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A Study of the Scup (Stenotomus chrysops), Based on Data Obtained from Catches of the 1963-64 Winter Trawl Fishery

Wallace Gibb Smith
College of William and Mary - Virginia Institute of Marine Science

A STUDY OF THE SCUP (*STENOTOMUS CHRYSOPS*), BASED ON DATA OBTAINED FROM CATCHES OF THE 1963-64 WINTER TRAWL FISHERY

by

WALLACE GIBB SMITH

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ABSTRACT

Length-frequency data and total landings were compiled from the marketable scup (Stenotomus chrysops) landed in Hampton Roads, Virginia, during the 1963-64 winter trawl season to determine the size composition of the stock or stocks exploited. The migratory habits of this species are thought to be temperature oriented; consequently, total landings increase as the season progresses and water temperatures decrease.

The formula describing the regression of weight on length for the total sample was found to be $\log Y = -4.7249 + 3.0391 (\log X)$. Both the sex ratio and growth rate of the sexes were found to be equal.

The formula describing the numerical relationship between fork length and scale radius was found to be $y = 60.5269 + (0.3198)x + (0.0064)x^2$. Although results of age determination by the scale method were not conclusive, average lengths of fish suspected to be one and two years old agree closely with findings reported by Bigelow and Schroeder (1953).

Catch per trip was selected as the most refined means available for determining the effects of fishing. Although information is lacking regarding the vital statistics of scup, there is no indication that this species is being overexploited.

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INTRODUCTION

The scup, Stenotomus chrysops (Linnaeus), or porgy as it is known in the southern part of its range, is the major component of the winter trawl fishery off North Carolina and Virginia and also figures prominently in catches of the inshore spring and summer fishery from New Jersey to Cape Cod. Though this species is economically important, very little is known about the life history, vital statistics, and the effects of fishing.

The U. S. Bureau of Fisheries began a study of marine fishes along the Middle Atlantic States in 1927. Data were collected on weakfish (Cynoscion regalis), summer flounder (Paralichthys dentatus), butterfish (Poronotus triacanthus), croaker (Micropogon undulatus), and black sea bass (Centropristes striatus); however, emphasis was placed on scup. This study continued through 1935 but it was not until recently that the results were published (Neville and Talbot, 1964).

Pearson (1932) described the beginning of the winter trawl fishery and provided valuable data on the composition of the catch and estimates of relative abundance based on catch per trip. Scup, black sea bass and summer flounder, in that order, have been the mainstays of the winter trawl fishery since the precipitous decline of the croaker. Despite the increased significance of scup, little scientific information has been compiled regarding this species since

Nesbit and Neville (1935) amassed data on the status of the winter trawl fishery from 1931 through 1934. They emphasized the relation of catches of scup, black sea bass, flounder and other species to water temperatures.

The initial objectives of this study were: (1) to determine the size composition and age structure of scup catches made by the winter trawl fleet; (2) to determine whether trends of catch and effort were apparent for years in which data were available; and (3) with the foregoing information in hand, to make preliminary assessment of the effects of fishing.

Most sampling was conducted in Hampton, Virginia, which is the major landing site of the fishery.

All data gathered in preparation of this paper are on file at the Virginia Institute of Marine Science, Gloucester Point, Virginia.

HISTORY OF THE FISHERY

The southern winter trawl fishery as described by Pearson (1932) began about 1920 when several New Jersey flounder draggers ventured south in an attempt to locate the large schools of croakers which annually migrated northward during March and April to the inshore waters of New Jersey. In the years that followed, fish dealers in the vicinity of Hampton and Portsmouth, Virginia, sent small shallow-draft oyster or crab dredge boats equipped with trawls down the North Carolina coast in search of croakers. These small converted boats would wait in Pamlico Sound for favorable weather prior to departing from Ocracoke Inlet for fishing on the open ocean.

Boats became so numerous about Ocracoke Inlet that the State of North Carolina in 1930 prohibited all trawling in state waters, thus seeking to protect their inshore pound net and seine fisheries. Passage of this law, which was preceded by similar legislation enacted in Virginia in 1926, severely curtailed the efforts of the small trawlers. They were not always able to work beyond the 3-mile limit during the stormy winter season. Moreover, flounders, their principal catch, were more abundant in the sandy inshore areas than on the more seaward fishing grounds. Nevertheless, approximately 20 of these small vessels continued to ply back and forth through Ocracoke Inlet during the winter of 1930-31.

By the winter of 1928-29, several large vessels from northern fishing ports, equipped for deep water trawling, were working regularly

along the coast of Virginia and North Carolina. The fishery developed rapidly the following year when additional northern trawlers joined the smaller Virginia fleet.

During the winter of 1930-31, the number of boats further increased to 25 northern trawlers and about 20 Chesapeake Bay vessels. Most catches were landed at ports on Hampton Roads. Wildwood, Cape May and Cold Spring Harbor, New Jersey, also received many of the landings.

The winter trawl season for scup generally begins in October when the first sizable catches are landed. Landings generally increase through April, then decline abruptly. By May, the trawler fleet shifts northward resulting in increased landings in New Jersey and New York.

The annual catches of four important species (scup, sea bass, flounder, and croaker) which comprised this fishery from 1929 through 1964 are given in Table 1 (U. S. Bur. Fish., 1931-41, and U. S. Fish and Wildl. Serv., 1942--63). As croaker stocks declined, fishing effort was diverted to the capture of scup and sea bass. The increased effort is reflected in the increased landings of these species since 1948.

During the 1963-64 season, 44 American vessels landed scup in the Hampton Roads area. In March 1964, personnel of the Bureauu of Commercial Fisheries conducted aerial surveillance on thirteen Russian stern trawlers fishing along the edge of the continental shelf near the 37°N parallel. This fleet represented the largest reported

number of Soviet vessels to operate in the area; however, American trawler captains have noted Russian fishing activities of lesser intensity since 1961. Although records regarding success of the foreign vessels are not available at this time, the Bureau of Commercial Fisheries estimated that the fleet was catching approximately 400,000 pounds of fish per day, most of which were scup and sea bass.

Monthly landings at Hampton Roads showing contributions by size class categories, their respective percentages, and total trips are given in Table 2. The classification of the catch into "large", "medium", and "small" does not follow a set standard. Fish ordinarily considered "small" are sorted as "mediums" when the supply is light to moderate. By the same token, large late season catches result in an increase of the minimum size specifications for all categories. Thus, when scup are plentiful, some fish earlier accepted as "small" are rejected, some "mediums" become "smalls", and some "large" are classified as "mediums". If wholesale prices are the same for "large" and "medium" fish, these categories are often combined and sorted as "mediums".

Table 1. Annual landings (pounds) of important species in the Virginia winter trawl fishery (U. S. Bur. Fish., 1931-41, U. S. Fish and Wildl. Serv., 1942-63).

Year	Scup	Black Sea Bass	Summer Flounder	Croaker	Total
1929	91,500	27,000	41,000	410,000	569,500
1930	311,517	171,366	249,464	962,780	1,695,127
1931	237,627	52,424	512,121	313,380	1,115,552
1932	1,688,966	835,405	601,761	1,593,625	4,719,757
1933	1,168,591	327,095	773,793	2,607,106	4,876,585
1934	659,500	115,900	474,300	2,837,100	4,086,800
1935	1,492,600	208,400	414,100	2,837,100	4,952,200
1936	853,200	42,300	269,900	5,753,000	6,908,400
1937	1,868,100	122,000	146,500	5,320,500	7,457,100
1938	2,301,300	230,500	438,400	2,650,300	5,620,500
1939	2,544,500	608,300	890,500	5,442,500	9,485,800
1940	3,228,700	509,900	1,022,300	6,059,000	10,819,900
1941	2,118,800	348,800	526,200	7,510,900	10,504,700
1942	2,394,500	185,500	331,400	4,596,800	7,508,200
1943		No Data Available			
1944	6,049,500	4,133,000	2,208,600	2,264,700	14,655,800
1945	4,806,000	2,267,700	1,042,100	14,126,500	22,243,300
1946	6,311,100	1,926,400	2,301,600	4,660,100	15,199,200
1947	4,801,100	3,329,000	1,191,100	7,219,400	16,540,600
1948	7,024,200	7,142,800	1,227,300	3,397,800	18,792,100
1949	5,955,400	4,195,600	1,641,800	1,623,800	13,416,600
1950	7,593,400	5,258,600	1,239,900	1,425,200	15,517,100
1951	10,054,600	8,721,900	1,488,200	1,431,700	21,696,400
1952	7,590,800	9,673,400	1,065,400	730,400	19,060,000
1953	8,357,800	6,459,100	1,263,400	749,100	16,829,400
1954	11,541,900	4,174,900	1,435,200	608,000	17,760,000
1955	13,144,100	5,039,800	1,004,400	1,663,000	20,851,300
1956	11,278,600	5,786,500	1,539,400	2,438,900	21,043,300
1957	6,321,900	3,807,800	1,185,900	2,622,100	13,937,700
1958	6,809,300	5,370,700	1,591,200	1,795,300	15,566,500
1959	11,517,800	3,065,100	2,745,700	746,900	18,075,500
1960	13,397,600	3,455,500	2,294,800	256,700	19,404,600
1961	11,255,800	3,018,600	1,895,300	131,200	16,300,900
1962	11,156,900	4,124,900	1,695,700	65,600	17,043,100
1963	9,550,300	4,311,600	1,535,500	96,000	15,493,400
1964	10,924,900	3,472,600	782,200	54,400	15,234,100[1]

[1]1964 data from Market News Service, U. S. Bur. Comm. Fish., Hampton, Virginia.

METHODS OF THE FISHERY

American vessels engaged in the fishery are side trawlers, mostly of wooden construction. They range from 60 to 110 feet in overall length and have a hold capacity varying from 40,000 to 170,000 pounds. Each trawler is usually equipped with such electric gear as sonic depth finder, fish finder, radar and loran. Vessels are crewed by four to six men who are paid on shares.

Trawling gear used to catch scup varies with the size of the vessel and individual preferences. The following description fits most of the gear used by the fleet. The wooden otter boards, known as eight-foot doors, are reinforced with steel and have a steel shoe, or bottom plate. The doors are 8' x 4' and each weighs approximately one-half ton. The towing warps, head line and foot rope are of 3/4" wire rope. The head line is approximately 62 feet in length and, under tow, is 18 to 20 feet in advance of the foot rope, which is about 88 feet in length. Forty-eight aluminum floats are attached at intervals along the head line. Wooden rollers threaded under the foot rope help prevent chafing and fouling. The vertical distance from head rope to foot rope varies from 6 to 7 feet under tow. The mesh size of the net tapers from 5 inches (stretch) at the mouth to 2¼ inches at the cod end.

Prior to the advent of fish finders, towing time averaged about two hours. However, the utilization of this electronic gear enables the captain to make a judgement as to the duration of a tow.

If signals on the spotting scope indicate the presence of a large school of fish, a productive tow can be obtained in as little as fifteen minutes.

If upon hauling, the amount of fish is found to exceed the maximum weight which can be brought aboard without risking damage to the net and/or gear, then the cod end is tied off, proceeding anteriorly, in successive sections. Each section is called a "bag" and contains approximately 3,000 pounds of fish. Large catches require rapid and coordinated effort on the part of the crew as the fish float for a limited time. While on the trawler Malolo, I had the opportunity to observe netted fish sinking when the split-strap (the line used to tie off the cod end) was broken while a portion of the catch was being brought aboard. This curtailed all efforts to bring the remainder of the catch aboard and resulted in the eventual loss of approximately one-half of the fish taken during the tow.

Vessels fishing primarily for flounder rig their nets differently in that only three aluminum floats are attached to the head rope and a tickler chain replaces the wooden rollers. Under tow, flounder gear has less height but greater width at the mouth of the net than those used for scup. Mesh size varies from net to net but is the same for all sections of a single net (Eldridge, 1962).

MATERIALS AND METHODS

Sampling of scup began in July 1963 when small, presumedly young-of-the-year were caught by the R/V Pathfinder during a monthly trawling survey on lower Chesapeake Bay and its tributaries. Fish were also obtained from this source in August. Samples of commercial pound net catches were obtained in August, September, and October from nets located near the mouth of the York River, Cape Charles, and Chincoteague; sampling consisted of taking individual fork length, weight, and scales.

After commencement of the winter trawl fishery in October, and continuing through April 1964, random samples were obtained from the commercial catch. Sample sizes varied from 25 to over 200 individuals and were generally dependent on the size of the catch and the time required for unloading the boat. In addition to obtaining fork lengths, weights, and scales, fish were obtained for sex determination. Interviews were held with the various boat captains whenever possible and inquiries made as to the areas and depths of catches of scup.

Fish were weighed (in grams) with a Fisher triple beam balance; a measuring board calibrated in millimeters was used for ascertaining lengths. Scales were taken from the left side of the fish in the area below the lateral line and immediately posterior to the pectoral fin. If an injury in this area was obvious, scales were collected from the same location on the right side. Approximately ten scales were taken from each specimen and placed in a labeled

envelope. After drying, five to eight scales from an individual were placed on 3 x 5 inch cellulose acetate sheets and pressed for three to five minutes under a pressure of 20,000 psi at a temperature of 150°F. A Carver Laboratory Press, Model B, was employed. An Eberhard scale projector was used to project scale images for study.

Otoliths were extracted from fish obtained for sex determination. Specimens were beheaded and the heads frozen. Otoliths were removed when time permitted and placed in labeled vials containing a 3% solution of tri-sodium phosphate. Clearing was attempted with glycerine, chloral hydrate, and beechwood creosote, none of which proved successful.

Information on individual trawler landings for the fishing seasons of 1957-58 through 1963-64 was obtained from purchase slips made available by Hampton Market News Service of the Bureau of Commercial Fisheries. A complete set of purchase slips was not available for the fishing season of 1960-61; however, estimates for the market catch were obtained by using the incomplete data and the reported total catch.

SEASONAL AND YEARLY TRENDS IN THE TOTAL CATCH AND SIZE COMPOSITION

The annual catch of scup, beginning in 1929 (Table 1) shows considerable fluctuation; however, since 1950, landings in excess of 10 million pounds have occurred in nine of the fourteen years reported.

Beginning in 1957, somewhat more detailed records are available which show not only the total landings for the fishing year but monthly landings further subdivided on the basis of the market categories i.e., size categories. Although market reports may reflect only in a general sense the size composition of the catch, the data do yield information on the general trends of the fishery (Table 2). Relatively light landings are made during the first few months of the fishing season, with catches consisting of a comparatively high percentage of "medium" fish. As previously noted, these sorting categories do not follow rigorous length specifications but may vary according to market conditions. Catch records reveal a trend toward greater landings and a higher percentage of large fish as the season progresses. A sharp decline in the catch occurs in May or early June because of the annual northerly migration.

The monthly catch and the total catch of small fish during the 1960-61 season were considerably lower than comparable landings from the other seasons excepting 1957-58 (Table 2). A possible explanation for the low catch of small fish in 1960-61 will be discussed in a later section.

Table 2. Monthly trawler landings of scup (thousands of pounds) by market sorting categories for the fishing years 1957-58 through 1963-64. Included are the percent contributions by market classes for each month and for the entire year. Fishing effort is expressed by the number of trips.

1957-58

	Large	%	Medium	%	Small	%	Total	Trips
Oct	68	12	375	68	109	20	552	25
Nov	116	20	336	57	137	23	589	33
Dec	193	25	425	55	149	20	767	35
Jan	168	25	259	39	234	35	661	62
Feb	357	42	352	42	134	16	843	60
Mar	330	32	459	44	245	24	1,034	63
Apr	316	28	462	41	349	31	1,127	86
May	187	20	514	54	252	26	953	38
Jun	13	17	51	66	13	17	77	5
Jul	-	-	-	-	-	-	-	-
Aug	-	-	-	-	2	100	2	1
Sep	16	23	45	66	7	11	68	3
Total	1,764	27%	3,278	49%	1,631	24%	6,673	411

1958-59

Oct	41	12	248	69	68	19	357	23
Nov	49	11	281	64	109	25	439	39
Dec	145	17	314	36	405	47	864	60
Jan	79	8	272	27	665	65	1,016	75
Feb	194	16	661	55	347	29	1,202	61
Mar	687	27	1,260	50	554	22	2,501	102
Apr	609	25	1,574	64	275	11	2,458	76
May	133	9	1,167	84	97	7	1,397	43
Jun	-	-	-	-	-	-	-	-
Jul	-	-	-	-	-	-	-	-
Aug	8	54	6	44	-[1]	2	14	2
Sep	-	-	-	-	-	-	-	-
Total	1,945	19%	5,783	56%	2,520	25%	10,248	481

[1]Less than 1,000 lbs.

Table 2 (continued)

1959-60

	Large	%	Medium	%	Small	%	Total	Trips
Oct	37	23	102	65	18	12	157	15
Nov	372	27	687	51	301	22	1,360	76
Dec	275	29	354	38	308	33	937	80
Jan	303	23	624	48	369	28	1,296	102
Feb	300	18	693	42	659	40	1,652	111
Mar	569	18	1,281	42	1,230	40	3,080	112
Apr	668	20	1,825	54	858	26	3,351	111
May	337	17	1,179	60	451	28	1,967	60
Jun	35	17	111	54	60	29	206	15
Jul	24	52	23	48	-	-	47	2
Aug	-	-	-	-	-	-	-	-
Sep	109	51	101	47	4	2	214	7
Total	3,029	21%	6,980	49%	4,258	30%	14,267	691

1960-61

Oct	23	10	187	82	17	7	227	18
Nov	94	16	301	52	187	32	582	60
Dec	121	28	195	44	121	28	437	67
Jan	173	20	439	50	261	30	873	82
Feb	258	21	583	49	359	30	1,200	88
Mar	385	22	1,156	67	194	11	1,735	67
Apr	756	22	2,283	65	428	13	3,417	73
May	189	17	770	70	144	13	1,103	39
Jun	1	2	67	93	3	5	71	3
Jul	-	-	-	-	-	-	-	-
Aug	-	-	-	-	-	-	-	-
Sep	-	-	-	-	-	-	-	-
Total	2,000	21%	5,931	61%	1,714	18%	9,645	497

1961-62

Oct	73	29	142	56	37	15	252	21
Nov	93	13	304	43	317	44	714	37
Dec	63	5	270	22	876	73	1,209	57
Jan	142	11	324	25	813	64	1,279	69
Feb	212	13	434	27	951	60	1,597	59
Mar	407	19	1,239	56	459	25	2,195	80
Apr	907	36	1,204	48	410	16	2,521	68
May	170	26	419	64	68	10	657	28
Jun	-	-	-	-	2	100	2	1
Jul	-	-	-	-	-	-	-	-
Aug	-	-	-	-	-	-	-	-
Sep	-	-	37	100	-	-	37	2
Total	2,067	20%	4,373	42%	4,023	38%	10,463	422

Table 2 (continued)

1962-63

	Large	%	Medium	%	Small	%	Total	Trips
Oct	90	15	436	70	96	15	622	21
Nov	155	18	339	40	360	42	854	54
Dec	216	23	376	41	334	36	926	63
Jan	221	17	458	36	591	47	1,270	80
Feb	303	26	258	22	602	52	1,163	71
Mar	395	32	121	10	726	58	1,242	82
Apr	625	37	800	48	259	15	1,684	58
May	92	21	271	62	74	17	437	19
Jun	-	-	6	100	-	-	6	2
Jul	-	-	-	-	-	-	-	-
Aug	-	-	-	-	-	-	-	-
Sep	-	-	7	100	-	-	7	1
Total	2,097	26%	3,072	37%	3,042	37%	8,211	451

1963-64

Oct	61	23	167	64	34	13	262	16
Nov	22	7	105	33	193	60	320	37
Dec	34	4	62	8	727	88	823	50
Jan	114	12	170	18	677	70	961	59
Feb	295	21	257	18	867	61	1,419	56
Mar	962	33	1,128	39	792	28	2,882	109
Apr	960	32	1,282	42	783	26	3,025	78
May	72	72	21	21	7	7	100	11
Jun	-	-	-	-	-	-	-	-
Jul	-	-	-	-	-	-	-	-
Aug	-	-	-	-	-	-	-	-
Sep	77	87	-	-	11	13	88	2
Total	2,597	26%	3,192	32%	4,091	42%	9,880	418

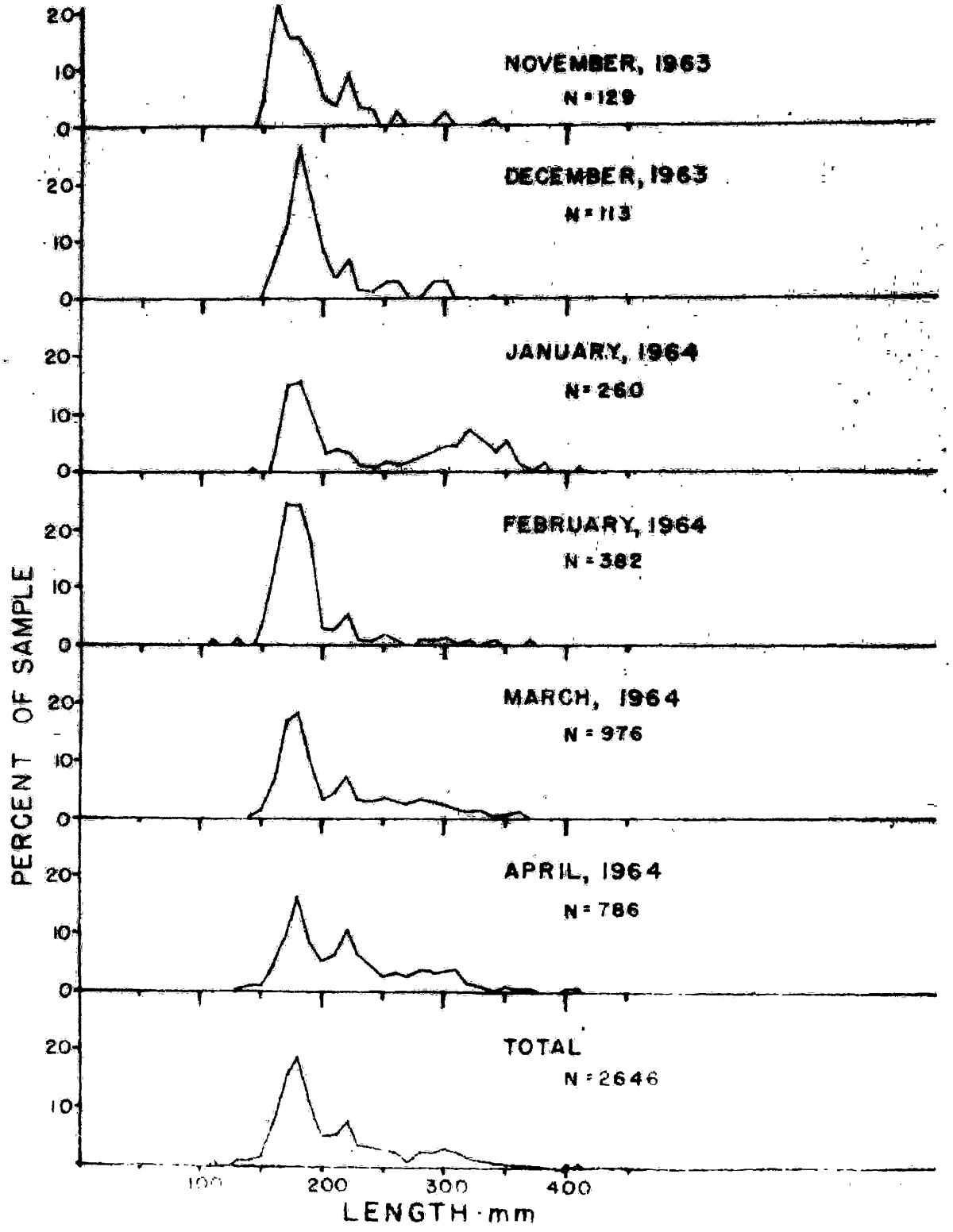
Data on monthly size composition and seasonal landing trends have been established for the 1963-64 fishing season and the length-frequency distributions are given in Table 3 and Fig. 1. Fork lengths were measured on 2,938 scup taken from the commercial catches landed in Hampton. Small, unsalable fish are culled at sea; therefore, nearly all landings are of market size. Fish obtained from sources other than the winter trawl catch were taken from Chesapeake Bay trawl surveys and from local pound net catches. These samples generally consisted of fish smaller than those landed by the commercial winter fishery.

Sampling effort was not proportional to monthly landings; therefore, an estimated length-frequency distribution of the year's catch based on random samples may have produced estimates which would be at variance with the true size class distribution of the total landings. In order to obtain a more accurate estimate of the size class distribution of the total catch, a method of adjustment was employed, as follows: (1) Because there was no apparent difference in the length-weight relationship for males and females, the data were pooled to obtain regression equations which yielded estimates of the average weight of fish representing the respective size class for each month. (2) The percentage contribution by size class for each month was multiplied by the total weight reported for the respective month by the Market News Service. This manipulation resulted in an estimate of the total pounds landed for each size class during the month. (3) For each month, the estimated total weight contribution by size class was divided by the respective average weight of fish comprising the size class to estimate the

Table 3. Length-frequency distribution of scup sampled at Hampton, Virginia, Nov. 1963-Apr. 1964.

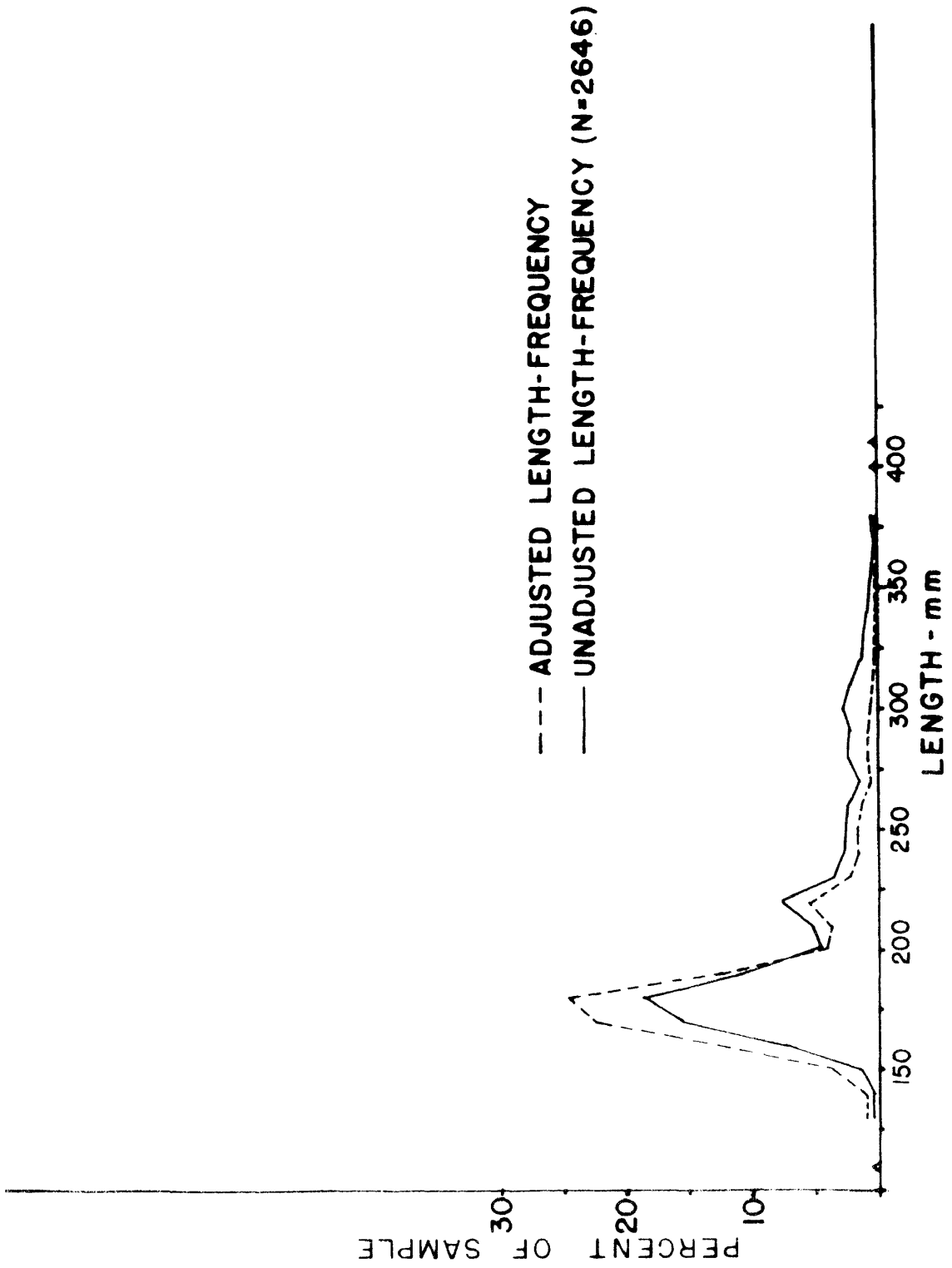
Fork Length/mm	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Total
110-119	1			1			2
120-129							
130-139				2		1	3
140-149			1		2	2	5
150-159	7	1		13	15	3	39
160-169	26	8	8	47	68	36	193
170-179	20	14	40	95	164	71	404
180-189	20	30	41	93	188	121	501
190-199	15	20	26	67	103	69	300
200-209	6	10	8	11	37	44	116
210-219	5	4	10	11	48	55	133
220-229	12	7	9	15	72	85	200
230-239	4	2	1	3	36	48	94
240-249	3	2	1	3	34	36	79
250-259		3	3	7	31	26	70
260-269	3	3	3	3	25	30	67
270-279		1	4		22	17	44
280-289		1	6	2	31	27	67
290-299	1	3	9	2	28	23	66
300-309	3	3	12	2	26	27	73
310-319			12	1	12	30	55
320-329			19	2	10	11	42
330-339	1		15		11	5	32
340-349	2	1	9	1	8	3	24
350-359			13		2	4	19
360-369			5		3	1	9
370-379			1	1		1	3
380-389			3				3
390-399							
400-409						1	1
410-419			1			1	2
Total	129	113	260	382	976	786	2646

Fig. 1. Size composition of scup samples by month and for the fishing season of 1963-64.



number of fish landed for each size class. Total numbers by size class by month were then obtained and percentages computed for each size class. The adjusted and unadjusted estimates appear in Fig. 2. It may be noted that a discrepancy occurs between the two methods for estimating the size class distribution of the total catch. Inasmuch as random sampling was rigorously followed during this investigation, it is concluded that differences occurred because sampling effort was not proportional to the landings.

Fig. 2. Length-frequency distributions of commercial landings of scup for 1963-64. The solid line indicates the length-frequency distribution obtained by random sampling of landings. The dashed line indicates the length-frequency distribution adjusted to include total landings.



AGE-GROWTH ANALYSIS

An arithmetic plot of the anterior scale radius on fork length was made to learn if scale growth was directly proportional to increase in length of the fish. The scatter diagram allowed two possible interpretations for a fit of the data. The scatter of points suggested a definite linear trend in the case of scales from fish of 60 to 200 mm fork length; from a fork length of 200 to 410 mm the points had a linear trend with a flatter slope. The entire range of points showed a curvilinear relationship with maximum inflection at a fork length of 200 mm.

To estimate the best fit for the entire range of scale and fork length measurements, scatter diagrams were prepared on semi-log and log-log paper. In neither case did the plots exhibit a straight line; therefore, the quadratic regression

$$y = a + bx + cx^2$$

was employed to fit a curve to the data by the least squares method (Snedecor, 1956). Measurements of 412 fish were used to compute the formula, which was

$$y = 60.5269 + (0.3198)x + (0.0064)x^2.$$

It is possible that the quadratic expression does not produce the best fit, but the data do imply a very definite change in the relationship of scale radius to fork length, particularly at a fork length of about 200 mm. This change may be a function of attainment of maturity. Whatever the cause of the apparent shift, the data strongly suggest that a direct proportion nomograph should not be used to back calculate lengths.

After derivation of the scale radius-fork length relationship, scales were studied to ascertain if age determination could be accomplished through scale analysis. Generally, the first ring was quite distinct on all scales, with the second annulus being less apparent (Fig. 3a). Scales collected from fish suspected of being older than three years (judging from the length of the specimen in question) frequently exhibited crowding of circuli and, furthermore, the sculpturing on scales from the same fish was repeatedly inconsistent. Very often a ring apparent in one area of the scale could not be traced in its entirety. Scales from large scup invariably bore evidence of erosion which was most pronounced in the area about the focus but was also apparent along the lateral portion (Fig. 3b). In many instances the position of the focus was arbitrarily selected because of erosion.

Because of the aforementioned complexities, the scales were considered unreliable in determining the age of scup. However, measurements from the focus to the first ring on scales of 242 fish yielded an estimated mean fork length of 97.5 mm at the time of ring formation. An estimated mean fork length of 153.3 mm at formation of the second ring was obtained from 139 specimens. These estimated fork lengths are in close agreement with figures cited by Bigelow and Schroeder (1953) for one and two year old fish, which suggests that the first two rings are indeed annual marks.

Otoliths were extracted for use as a check on age determinations derived from scales. The sagitta or sacculolith, formed in the sacculus of the inner ear, was chosen for this study. Sagitta of

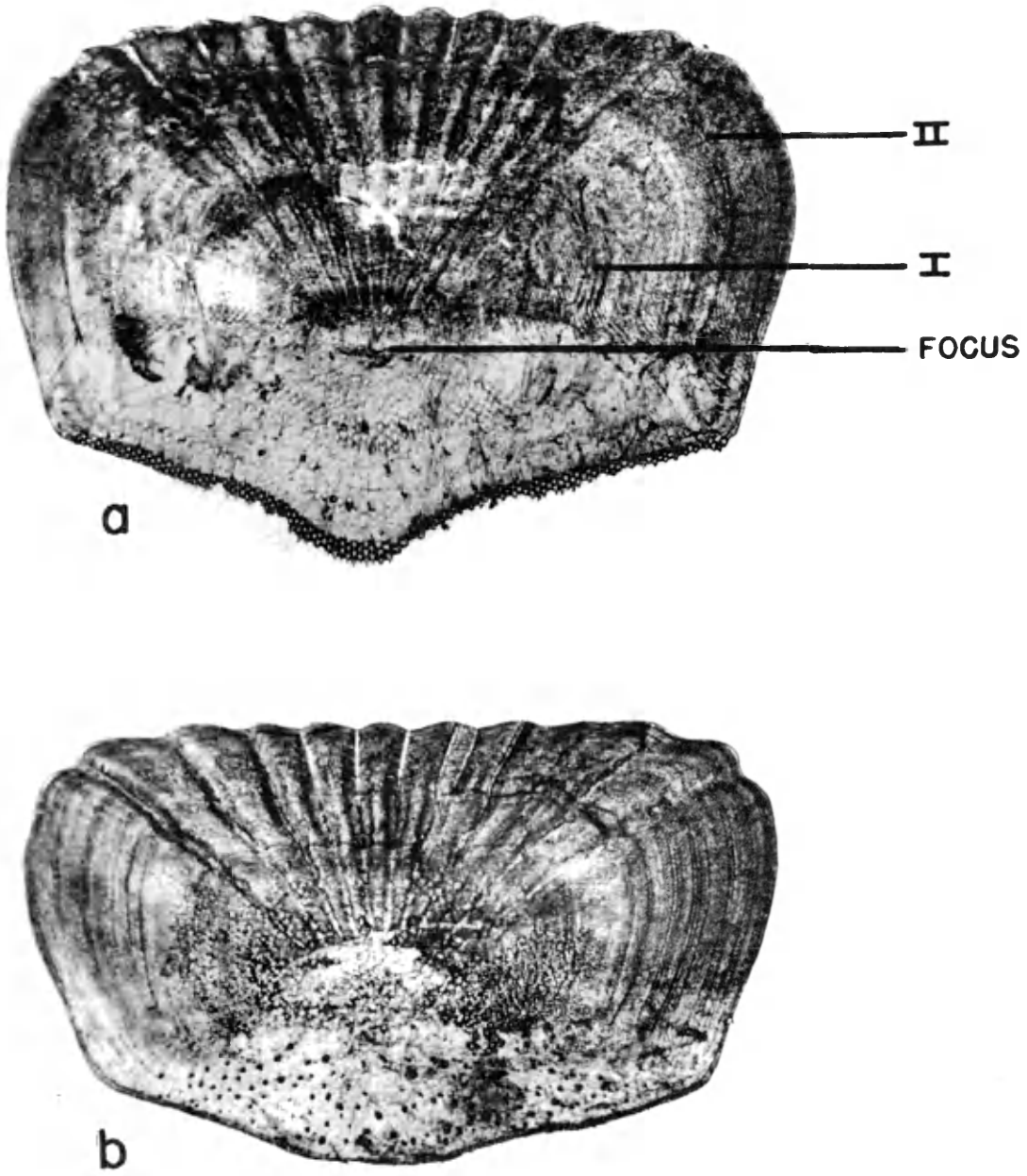


Fig. 3. Photographs of scup scales, showing; (a) the focus and two rings of a specimen having a fork length of 203 mm, and (b) erosion in the area about the focus of a specimen 347 mm fork length.

scup are roughly boat-shaped and when viewed from the top or bottom are seen to be concavo-convex. The sagitta is opaque, particularly in the thicker central portion, with the opaqueness becoming more pronounced as the fish grows. Various clearing agents were employed without success in an attempt to distinguish annuli. In several sectioned sagitta the rings appeared to be in some accordance with those found on scales, and it was concluded that sectioning is necessary to properly assess the value of otoliths as a means for determining the age of scup. Because equipment for sectioning otoliths was unavailable, this aging technique was not further pursued.

LENGTH-WEIGHT RELATIONSHIP

Mathematical formulae were derived to describe the relationship of length to weight. These formulae allow for a conversion from length to weight and give a comparison of length-weight relationships between the sexes.

Paired lengths and weights for monthly samples, each sex, and for the total sample were plotted on arithmetic paper. Results were curvilinear in all instances. Length-weight measurements of the total sample exhibited a linear trend when plotted on log-log paper; thus, the formula

$$Y = aX^b$$

was used to describe the relationship. When length and weight measurements are converted to logarithms the formula becomes

$$\log Y = \log a + b(\log X).$$

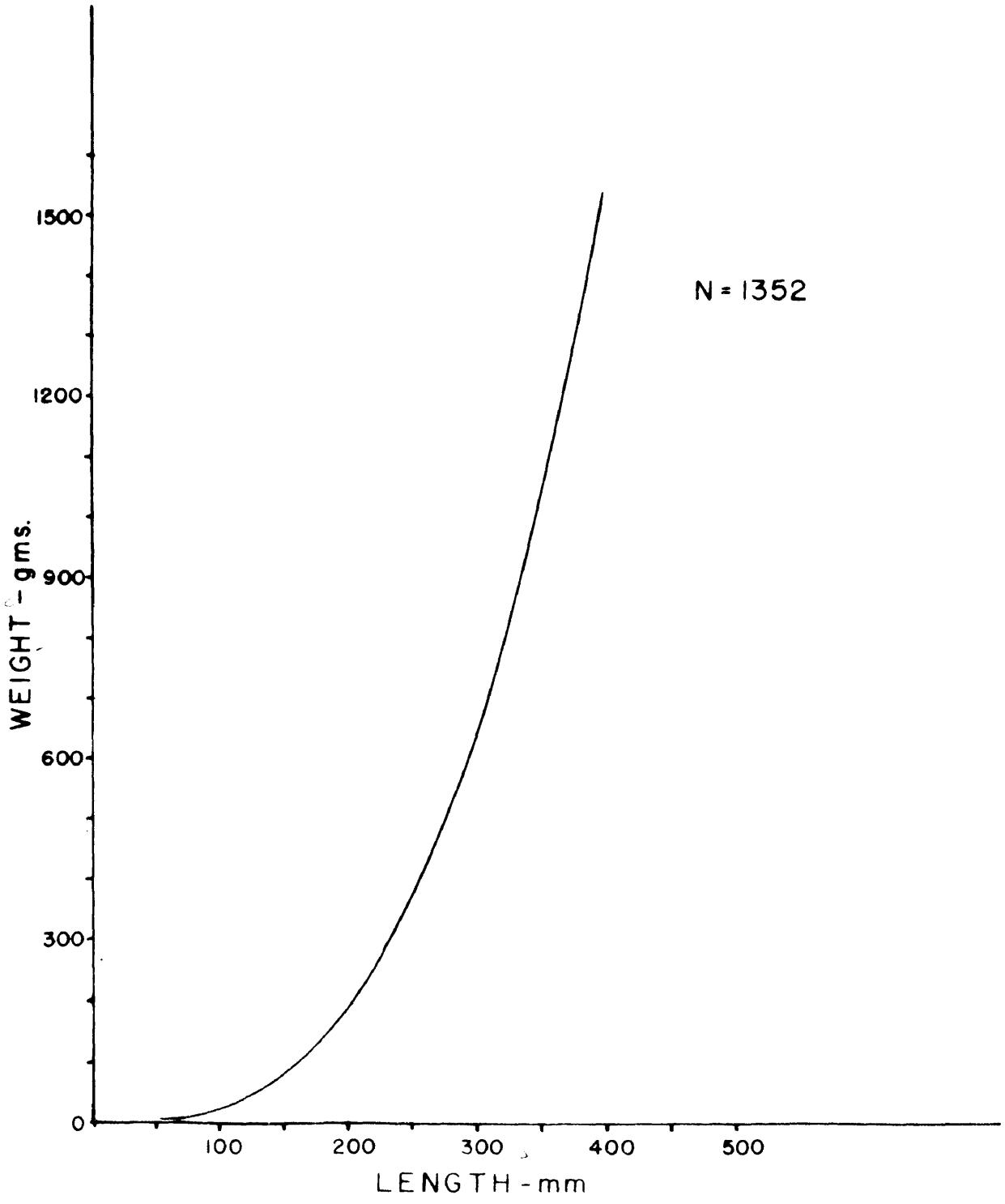
The elevation or intercept (a) and the regression coefficient (b) were obtained by the least squares method. The regression equations were derived through the use of an IBM 1620 computer.

The formula describing the regression of weight on length for the total sample is

$$\log Y = -4.7249 + 3.0391(\log X).$$

The curve developed from the formula is shown in Fig. 4. Empirical data are not plotted on the graph to indicate the goodness of fit. However, a measure of variability of weight on length ($R^2 = 0.986$) indicates that 98.6% of the change in weight is due to regression on length.

Fig. 4. Length-weight relation of scup sampled from July 1963 through April 1964.



The sex ratio was determined from 303 fish which were not selected randomly but chosen in nearly equal numbers from the market sorting categories of "large","medium", and "small". Gross gonadal examination revealed 144 males, 146 females and 13 of indeterminate sex. The sex ratio of the population was considered to be 1:1.

Regression equations for the relationship of length to weight for males, females and for each month of sampling are given in Table 4. Although the regression equations differed slightly, visual comparisons of the curves drawn from the equations indicated only minor differences, adjudged in this case to be due to sampling error. Despite the advanced stage of gonadal development by the end of April, the length-weight relationship between the sexes did not appear to differ from comparable measurements taken during preceding months. The length-weight relationship for either sex, or for any month covered by this investigation did not vary significantly. Nevertheless, it is not improbable that shortly before spawning, which occurs mostly in June, females weigh more than males of the same length.

Table 4. Regression equations by month and sex for fish sampled from winter trawl fishery.

	N	LENGTH RANGE (mm)	WEIGHT RANGE (g)	REGRESSION EQUATION
DATE				
Nov 1963	127	114 - 345	33 - 945	log Y = -4.5064 + 2.9599(log X)
Dec 1963	69	155 - 342	106 - 1007	log Y = -4.6492 + 3.0151(log X)
Jan 1964	48	166 - 336	166 - 336	log Y = -4.3483 + 2.8819(log X)
Feb 1964	173	118 - 341	35 - 956	log Y = -4.6110 + 2.9845(log X)
Mar 1964	86	153 - 374	76 - 1068	log Y = -5.0886 + 3.1871(log X)
Apr 1964	127	163 - 381	95 - 1290	log Y = -4.7213 + 3.0328(log X)
SEX				
Males	144	167 - 374	105 - 1068	log Y = -4.7468 + 3.0435(log X)
Females	146	161 - 381	81 - 1290	log Y = -4.6957 + 3.0249(log X)

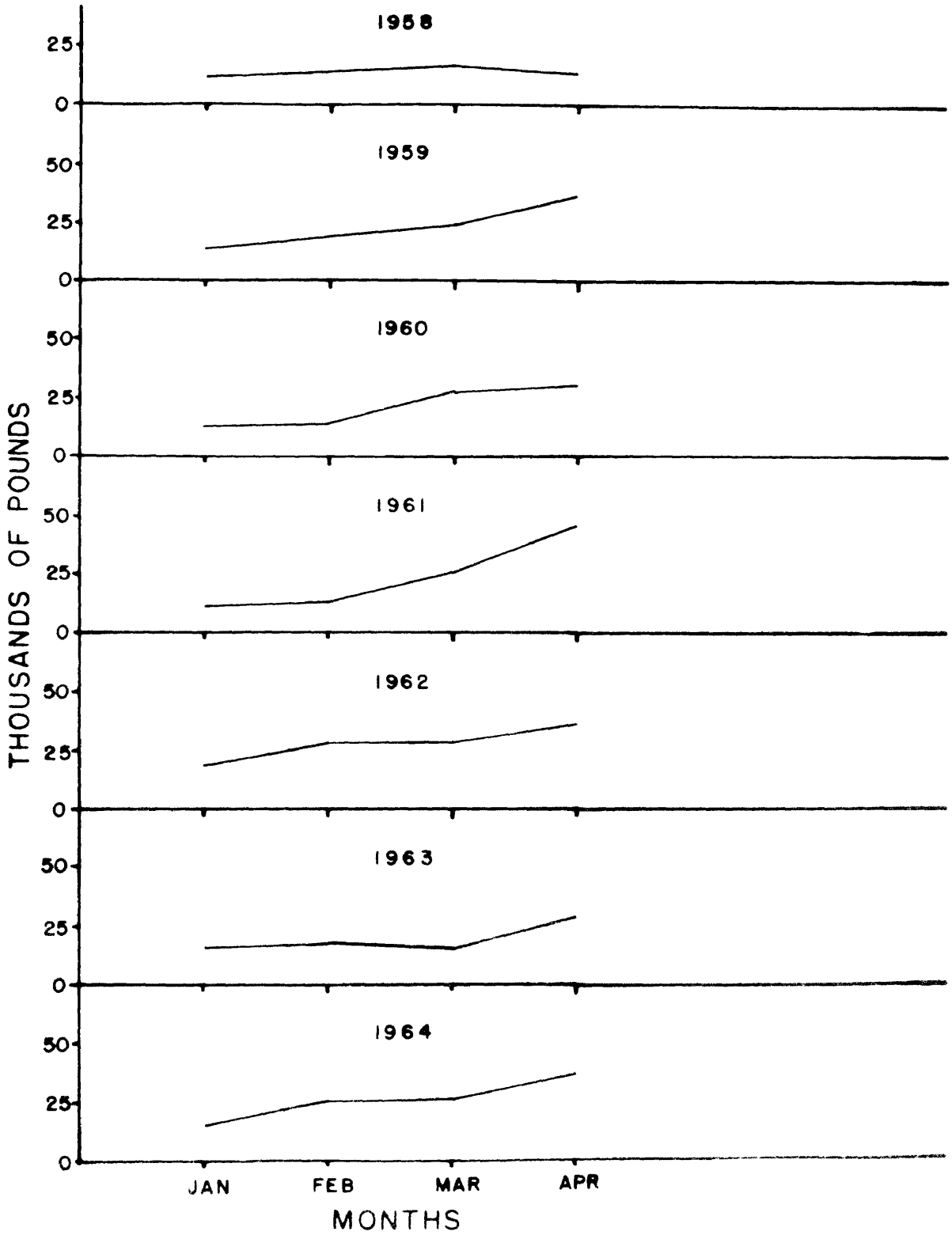
DISCUSSION

Although data on the size composition of the catch and other related data are necessary to evaluate the biological status of the resource, additional information is also relevant for a fuller understanding of the fishery. Boat captains were interviewed in an attempt to determine the areas fished, and more particularly, to learn if there was a seasonal shift from area to area by the fleet. Although interview data are sparse, it appears that during the early months of the fishing season the trawlers are widely scattered over shelf waters from New Jersey to North Carolina where trawling is done from depths of approximately 20 to 120 fathoms.

Trawler activities (areas fished) give some indication of the seasonal distribution of scup but of particular interest here is the report of Nesbit and Neville (1935) relating scup distribution to water temperatures. These authors found that the best catches of scup were made in waters having bottom temperatures of 45°F or greater and postulated that as water temperatures decreased, scup became more restricted in their range with a subsequent increase in availability to the gear.

Although no data on temperature are available for recent years, the change in availability as evidenced by increasing catch per effort from January through April for the years 1958-1964 (Fig. 5) indirectly supports the contention that scup become concentrated with decreasing water temperatures. Decreasing water temperatures may also

Fig. 5. Monthly (January through April) catch per trip (thousands of pounds) for 1958-1964.



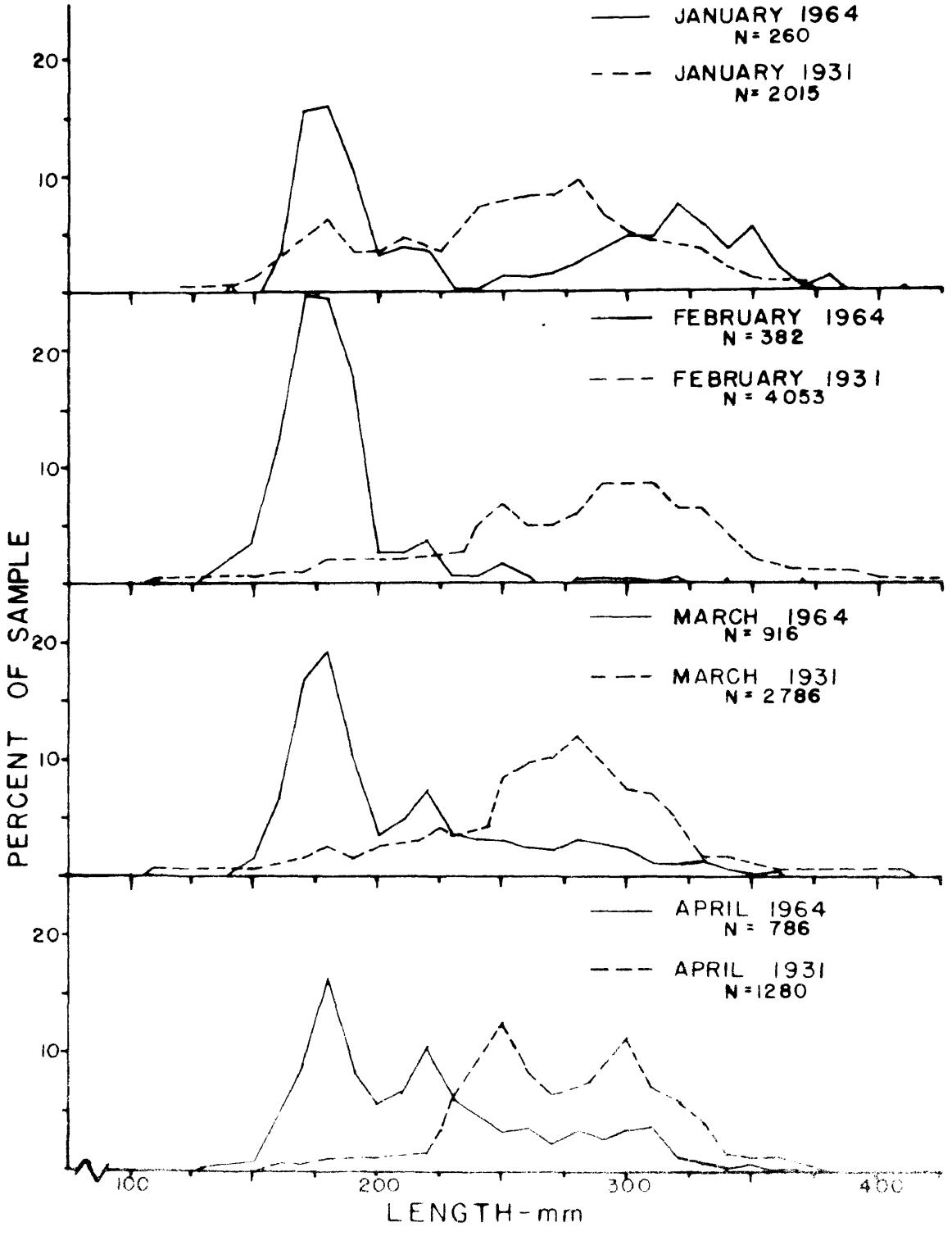
serve to concentrate undesirable species of fish, for frequently dogfish (Squalus acanthias) shoals are found in the same general areas frequented by scup and sea bass. When schools of dogfish are encountered, fishermen avoid the area temporarily because, if caught in large numbers, dogfish may cause extensive damage to the net as well as loss of time and effort.

Edwards et al. (1962) reported that the 1958 spawning season of scup was virtually a failure. The comparatively low total weight and percentage of "small" fish landed during 1960-61 (Table 2) substantiates these findings, for in all probability the majority of fish that comprised the "small" category in 1960-61 consisted of the 1958 year class. It is interesting to note the marked increase in "small" fish landed the following season.

It may be noted from Table 2 that there were more trips recorded for 1959-60 than for the other seasons. The increase in trips per season is attributed to an increase in the number of vessels operating during the 1959-60 season and not to additional effort by individual trawlers.

Early records published by Pearson (1932) allow for a comparison of length-frequency distributions of catches from a newly developed fishery with the size composition of the catch some 33 years later (Fig. 6). Measurements taken by Pearson varied from 110 to 480 mm with the majority of fish having a fork length of 200 to 350 mm. The mode for the 1931 data occurs at 280 mm during all months except April. Size composition data for 1964 show a pronounced mode of 170 to 180 mm. With the exception of January, a lesser mode

Fig. 6. Monthly length-frequency distributions comparing data collected by Pearson (dashed line) with recent data (solid line).



occurs at 220 mm. This shift in mode from 280 to 180 mm is suggestive of the effects of fishing. Whether fishing is of such intensity as to materially reduce the numbers of fish attaining a size in excess of 280 mm is questionable because the total catch for months reported by Pearson is only about one-fifth that of the 1964 catch. In any event, it is apparent from the length-frequency distributions (Fig. 6) that a number of year classes contribute to the fishery--an important consideration in fisheries management.

Although conclusive age determinations were not made and estimates of natural mortality rates are not available, the growth rate of this species allows for some speculation as to the benefits that would accrue to fishermen through adoption of larger mesh size. Neville and Talbot (1964) reported that one and two year old scup average 165 and 205 mm, respectively, in autumn. From these figures and the length-weight relationship obtained during this study (Fig. 4), it is estimated that one and two year old scup weigh on the average of 100 to 200 g, respectively, by fall, when the seasonal commercial fishery commences.

Fish less than 165 mm in fork length command the lowest prices and, in fact, under most market conditions are refused by the dealers. Assuming mortality as high as 50% for fish over 165 mm, there would be no change in total poundage of fish available the following year if net mesh were such as to allow escapement of fish under 205 mm.

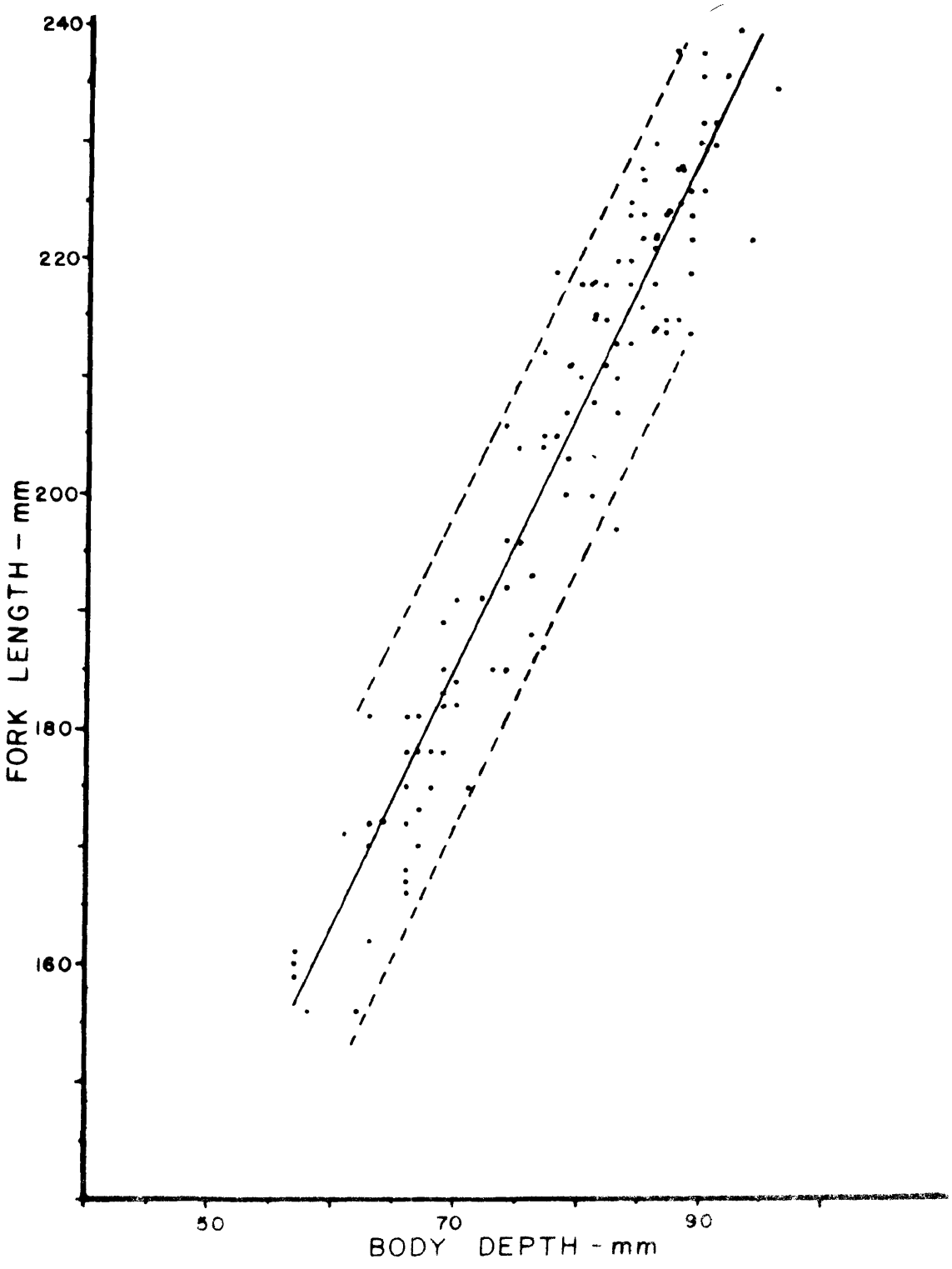
The selection of a mesh size which would allow escapement of most scup under 205 mm fork length would probably have to be determined by trial and error. However, a plot of fork lengths on

body depths (Fig. 7) affords data on which to base the initial selection of larger net mesh. Confidence limits on the regression line (Fig. 7) allow for some estimate as to the length of fish that could escape from a given mesh. For instance, it may be noted that 95% of scup with a body depth of 75 mm have a fork length between 183 and 210 mm. A cod end which has a mesh of about 4 inches (stretch) would have a diagonal mesh opening of approximately 3 inches, under tow. This would allow escapement of scup up to 210 mm and virtually all fish below 183 mm. Of further interest in the adoption of larger mesh is the result of an experiment cited by Graham (1956). In brief, this experiment involved fishing side by side two nets with a 10 mm difference in mesh size. Not only did the larger mesh allow escapement of small fish, but it caught greater numbers of larger fish, presumedly because the larger mesh allowed freer flow of water through the net.

Suffice it to say that by increasing net mesh size, fishermen would probably realize greater profits because market prices generally increase as fish become larger and a self-culling net would reduce time spent in sorting the catch. These assumptions are made with full awareness that the winter trawl fishery is not a single species fishery and that some compromise for mesh size would have to be made.

In order to correctly assess the effects of fishing, several criteria must be considered. Catch records alone may not indicate the abundance of a given species. A stock may be on the decline, but through expanded effort, total landings may actually increase.

Fig. 7. The body depth-fork length relationship of scup showing the regression line (solid), the 95% level of confidence (Sy·x t.05) (dashed), and an empirical plot to indicate the goodness of fit.



This fact taken alone may result in erroneous conclusions regarding the status of the fishery. Consideration must be given to numbers, type, and efficiency of the different gears employed. The length of time a unit of gear operates, and changes in availability of the stocks to the gear must also be considered.

The number of vessels fishing for scup fluctuates from season to season. Fishing effort varies within a given season and is often affected by demand for a particular species, by periods of adverse weather and by mechanical break-down. The otter trawl is the only gear employed in the winter scup fishery and because all nets are of similar dimension, gear efficiency is considered consistent. Availability of the species increases as the season progresses but appears relatively consistent from year to year.

The length of time from port to port is limited by supplies, distance to the fishing grounds, and time required to locate the fish. Because trawler captains do not keep records on the number of tows made or the actual time spent fishing, catch per trip was adopted as the most refined unit of effort available for detecting apparent changes in the fishery. The accuracy of such a unit is affected by the lack of records pertaining to the number of small, unmarketable fish culled at sea and occasional diversion of effort from scup to a more profitable species when supply exceeds demand.

During 1931, Pearson (1932) reported landings of scup to range from several pounds to 48,000 pounds per trip. Approximately 55% of the landings in 1931 consisted of not more than 8,000 pounds

of scup. The data afforded by Pearson allow for the determination of catch per trip for the 1930-31 fishing season; however, various developments since the advent of the fishery make a comparison of catch per trip between 1931 and 1957-64 unfeasible. As previously mentioned, nearly half of the early trawl fleet was made up of small boats which, in addition to having less hold capacity, were usually limited to fishing well inshore of what appears to be the major winter range of scup. Much of the effort of the early fishery was well to the south of today's fishing operation, thus it is presumed the early fleet did not operate in areas of maximum abundance of scup. Furthermore, the crews and vessels of today are without doubt more efficient than those of the late 1920's and early 1930's, if for no other reason than the utilization of fish-finding gear.

With the exception of the comparatively light catch per trip in 1957 (Table 5), which is attributed to a decrease in trips during the peak months of January through April, the relative consistency of total landings and of the individual market size categories, as well as the consistent catch per trip data (Fig. 5), suggest that the stock or stocks are not being overexploited. Further evidence of a stable fishery is to be noted by the relative consistency in percentages of "large", "medium", and "small" fish landed from 1957 through 1964 (Table 2).

Although information presented herein suggests that the winter trawl fishery is having no adverse effects on the scup stock or stocks, a definite statement regarding the effect of fishing must be deferred until such time as estimates are obtained regarding the

Table 5. Catch (thousands of pounds) and catch per trip (hundreds of pounds) by size class categories for the fishing years 1957-58 through 1963-64.

		Large	Medium	Small	Total
1957-58	Catch	1,764	3,278	1,631	6,673
	Trips				411
	Catch/Trip	43	80	40	162
1958-59	Catch	1,945	5,783	2,520	10,248
	Trips				481
	Catch/Trip	40	120	52	213
1959-60	Catch	3,029	6,980	4,258	14,267
	Trips				691
	Catch/Trip	44	101	62	206
1960-61	Catch	2,000	5,931	1,714	9,645
	Trips				497
	Catch/Trip	40	119	34	194
1961-62	Catch	2,067	4,373	4,023	10,463
	Trips				422
	Catch/Trip	49	104	95	248
1962-63	Catch	2,097	3,072	3,042	8,211
	Trips				451
	Catch/Trip	47	68	67	182
1963-64	Catch	2,597	3,192	4,091	9,880
	Trips				418
	Catch/Trip	62	76	98	236

vital statistics of this species. Needed but lacking are estimates on (1) natural mortality, (2) recruitment, (3) age at maturity, and (4) the population structure of the scup resource along the western North Atlantic.

The exploitation by the Russian trawl fleet is worthy of emphasis at this point. If foreign participation continues to be an annual occurrence, and if the annual harvest by the American fleet approaches the yearly gain in biomass, then the added effort by the Russian fleet should be quickly evident in a decrease in catch per unit of effort, in the reduction in average length of fish comprising the catch, and finally, a drastic reduction in the yearly landings.

SUMMARY

1. Data on the size composition were complied from commerical catches of scup landed in Hampton Roads, Virginia, to establish a base line for detecting future changes which may occur in the size composition of the stock or stocks.

2. The mathematical formula describing the regression of weight on length for the total sample was found to be log Y = -4.7249 + 3.0391(log X). Regression equations computed for males, females, and for each month of sampling differed slightly. These minor discrepancies are considered to be due to sampling error.

3. The sex ratio of the stock or stocks of scup available to the winter trawl fishery is considered to be 1:1.

4. Monthly landings increased and the size composition of the catch shifted from smaller to larger fish as the season progressed. These changes in the catch are considered to be due to the temperature-oriented migratory habits of scup.

5. The formula describing the fork length-scale radius relationship was found to be $y = 60.5269 + (0.3198)x + (0.0064)x^2$. Scup have an average fork length of 97.5 mm and 153.8 mm, respectively, when the first and second annuli are formed. However, a conclusive technique for age determination was not resolved.

6. Seasonal landings and units of effort (catch per trip) were compiled to determine the status of the fishery. Although the existing data are limited, the size composition of the catch and the catch per trip suggest that the stock or stocks of scup available to the winter trawl fishery have not been overexploited.

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